SYNTHESIS, STRUCTURAL, MORPHOLOGICAL AND ELECTROCHEMICAL PROPERTIES OF 2D MATERIALS AND THEIR COMPOSITE FOR SUPERCAPACITOR APPLICATIONS

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Submitted By

VIJAYKUMAR SIDDAPPA PUJAR

Ph.D. student

Under the supervision of

Dr. DEVENDRAPPA H

Professor

Department of Studies in Physics,
Mangalore University
Mangalagangotri, Karnataka - 574 199.

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Ph.D. Registration Details

Name of the Candidate	Vijaykumar Siddappa Pujar Ph.D student Department of Physics, Mangalore University, Mangalagangothri-574199.
Name of the Research Guide	Dr. Devendrappa H Professor Department of Physics, Mangalore University, Mangalagangothri-574199.
Address of the Work Place	Department of Physics, Mangalore University, Mangalagangothri-574199.
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1. Introduction

Recent year's developing of the scientific research and nanotechnology of the new unique materials to promoted industrial product for fulfillment of the global world demands and consumption of source material and bring new affordable technology also. However, the electrochemical storage, energy conversion, sensors, light emitting diode and photovoltaic techniques are emerged as a prominent gadgets use in digitalization, portable device and internet network etc, among all electrochemical storage have gained increased attention due to their diverse range of applications, flexible operating processes, simple device fabrication, long-term stability, accurate results, user-friendly protocols, and stable electrode performance. These advantages are made the electrochemical technique is widely utilized in a variety of areas, including supercapacitors, batteries, fuel cells, electrochemical sensors, bio-sensors, electrochemical corrosion, hydrogen evolution, bio-imaging, biological electrochemistry, photovoltaics, and electro-catalysis. The energy storage devices are inevitable candidates in the field of energy preservation and its utilization. In general, the four types of energy storage through mechanical, electrical, chemical, and electrochemical systems have been employed for various applications, including large-scale energy conservation [1]. As a new type of energy storage element, a supercapacitor has great potential in the energy field due to its high-power density [2,3], It has the advantages of high discharge power, long cycle life, wide operating temperature range, and environmental affectionate. It is the core device in the energy storage system [4], due to the pure electrostatic energy storage mechanism, compared with other energy storage systems based on electrochemical conversion (such as batteries), supercapacitor is also having the characteristics of high specific capacitance, low internal series resistance, low-cost consumption, and fast charging-discharging speed. supercapacitors also known as ultracapacitors, are energy storage devices that bridge the

gap between traditional capacitors and rechargeable batteries, which combines the high-current fast charging- discharging characteristics of an ordinary capacitor and the energy storage characteristics of a battery, filling the gap between an ordinary capacitor and batteries plays a significant role, especially in electric vehicles and portable electronics [5,37].

Supercapacitors can be classified into three main types based on their charge storage mechanisms: electrical double-layer capacitor (EDLC), pseudocapacitors and hybrid capacitors. The EDLCs store electrical energy through ion absorption, while pseudocapacitors primarily store energy via fast surface redox reactions, and hybrid supercapacitors combine the characteristics of both EDLC and pseudo capacitors [6-8]. Generally, carbon-based materials are commonly used as electrodes for EDLCs, while conducting polymers and transition metal oxides are employed in pseudocapacitors and the hybrid supercapacitors used both the materials used in EDLCs and psedocapacitors. The distinct working mechanisms of material decide the different performance, EDLCs utilizing carbon materials exhibit excellent cycling stability and high-power density but relatively low capacitance and energy density. Conversely, pseudocapacitors display the opposite behavior. However, it should be noted that the electrode chemical reactions in pseudocapacitors can lead to the accumulation of irreversible components during cycling as a result in deteriorating performance. Moreover, the combination of both mechanisms known as hybrid supercapacitor, the hybrid supercapacitors employ both EDLC and pseudocapacitive charge storage, leading to elevated capacitance compared to EDLCs and better cycling stability and device efficiency than pseudocapacitors. Simultaneously, they enhance their energy density without compromising power density. Despite these advantages, a major drawback of supercapacitors is their low capacitance and energy density. Therefore, it is a need to enhance the capacitance and energy density without compromising power density and cyclic stability. According to the energy density equation,

$E=1/2CV^2$, increasing the voltage window and specific capacitance can enhance the energy density of supercapacitors. An alternative approach is to develop hybrid electrochemical capacitors, such as symmetric and asymmetric supercapacitors. Since the electrode material is crucial to supercapacitor performance, various materials, including conventional 2D materials, carbon materials, transition metal dichalcogenides, conducting polymers, metal oxides, and sulfides, have been widely investigated.

Among these, two-dimensional (2D) materials have attracted significant research interest due to their outstanding physicochemical properties [9-13]. These materials have an ultrathin lamellar structure, but different functionalities for different applications. So far, a large family of 2D materials has been reported, such as graphene, graphene oxide (GO)[14], reduced GO (rGO)[15], 2D transition metal dichalcogenides (TMDCs) [16-17], hexagonal boron nitride (h-BN) [18], black phosphorene (b-P) [12], black arsenic phosphorene (b-AsP)[19], graphitic carbon nitride (g-C_3N_4) [20], etc. There is no doubt that 2D materials have become the research interest of scientists and engineers in a wide range of fields, because of the large number of species, their unique properties, versatile functionalities, and promising applications in electronics, optoelectronics, energy storage and conversion etc. Two-dimensional (2D) materials are considered ideal electrode materials for supercapacitors due to their low cost, environmental friendliness, high power density, and excellent specific capacitance [22]. However, 2D materials often have low electrical conductivity, energy density, and weak electrochemical stability, which means they limits their suitability for high-specific-capacitance supercapacitors [23]. In order to get over these restrictions and improve the electrochemical performance of 2D materials, they are made utilizing various precursors and synthesis techniques, which will enhance the supercapacitor applications. For example, Graphene-based supercapacitors started appearing in scientific literature and research around 2008. While the

concept of supercapacitors existed before, the application of graphene significantly advanced the technology due to its unique properties [24]. Additionally, Use of graphitic carbon nitride (gC_3N_4) in supercapacitor applications started gaining attraction in the past decade, particularly around 2018, when research papers began highlighting its potential for energy storage [25]. Next advanced methods for enhancing supercapacitors are 2D materials like g-C_3N_4 are incorporated with conducting polymers such as polyaniline (PANI), polypyrrole (PPy), polyacetylene (PAC), and polythiophene (PT), are incorporated with 2D g-C_3N_4 to overcome these limitations and enhance the electrochemical performance [26]. Among these conducting polymers, PPy stands out as a strong contender for electrode applications due to its high electrical conductivity, excellent mechanical quality, high specific capacitance, and superior biocompatibility [27]. Additionally, 2D transition metal dichalcogenides have also proven to be suitable supercapacitor electrode materials. Recent studies have reported composites of 2D materials with exceptional chemical properties, large surface area, and excellent electrical and thermal properties, making them suitable for supercapacitor electrodes. MoS_2 stands out among the TMDs, serving as a unique material that is used for supercapacitors because of its significantly larger potential window, low cost, and low toxicity, which also makes a g-C_3N_4 a usable electrode material and highlighted the high-performance capacitive behavior of g-C_3N_4/MoS_2 composites. Recent, the 2D material related studies have highlighted significant advancements in supercapacitor applications are discussed below.

C. J Verma et al. fabricated a g-C_3N_4 /Polyindole composite electrode that displayed a specific capacitance of 115.8 F/g at 2 A/g [28], **X. Chen et al.** PEDOT/ g-C_3N_4 with a specific capacitance of 137 F/g at a current density of 2 A/g [29].

R. Arora et al. reported that Graphitic carbon nitride (g-C_3N_4) and polypyrrole (ppy) nanocomposites detected that 0.4 pcn has the highest specific capacitance value of 555 F/g at 10 mV/s scan rate through CV and 475 F/g at a current density of 0.5 A/g. This composite exhibited good cyclic stability with high retention. The high energy density of 0.4 pcn composite is analysed at 86 Wh/kg at a power density of 300 W/kg [30].

Preetam Bharadiya et al. reported the PANI/10 wt% GO nanocomposite electrode exhibited the highest specific capacitance of 276 F/g, compared to 180 F/g for pure PANI. The PANI/GO10 nanocomposites were also more stable over time. After 500 cycles at a current density of 0.5 A/g, they still had 80% of their original capacitance, while pure PANI was unstable [31].

K Yogesh Kumar et al. studied the supercapacitor performance of the GO-RuO_2 nanostring composite exhibited a maximum specific capacitance of 859 F/g at a scan rate of 5 mV/s, as determined by cyclic voltammetry. Using chronopotentiometry, the specific capacitance further increased to 512 F/g at a current density of 2.5 A/g. Additionally, the material demonstrated a high energy density of 246 Wh/kg and a maximum power density of 1028 W/kg. The GO-RuO_2 nano string composite electrode also exhibited excellent cyclic stability, retaining nearly 99% of its initial capacitance [32].

Songzhan Li et al. proposed that $MoSe_2/MoS_2$ composite delivers a significantly enhanced supercapacitance performance, with a high specific capacitance of 1229.6 F/g at 1 A/g and 92.8% capacitance retention after 2000 cycles. [33].

Jing Xu et al. reported that the electrochemical properties of the as-prepared g-C_3N_4/MoS_2 heterojunction are evaluated by cyclic voltammetry and galvanostatic charge/discharge tests, which

indicate the optimal g-C_3N_4/MoS_2 exhibits remarkable electrochemical performance with a high specific capacitance of 532.7 F/g at a current density of 1 A/g and excellent cycling stability with 88.6% of capacitance retention at 1 A/g after 1000 cycles [34].

Sajjad Hussain et al. studied assembled WS_2@MXene/GO nanocomposites electrode produced a superior specific capacitance of ~ 1111 F/g at 2 A/g applied current. WS_2@MXene/GO composites electrodes were studied using repeated GCD tests at an applied current 10 A/g, After 5,000 cycles, 97.15 % of their primary capacitance [35].

Halder P, et al. elaborate the phosphorene nanosheets CV and GCD measurements in the potential window of -0.7 V to 0.1 V revealed its highest pseudo-capacitance response (84.91 %), reaching a maximum specific capacitance value of 759.748 F/g at current density 2 A/g, surpassing all previous records. Moreover, BP displayed excellent cyclic stability of 89.8 % after 10,000 cycles, making it an excellent electrode material for supercapacitors, achieving maximum specific energy density at 73.43 Wh/kg at a power density of 1500 W/kg [36].

According to the literature review, 2D Material based composites are promising for energy storage due to their high specific capacitance, energy and power density, rapid charge/discharge capabilities, and long lifespan. The current study aims to construct a solid-state symmetrical supercapacitor device using two-dimensional materials and their composites, including gC_3N_4/MoS_2, gC_3N_4/PNT composites, and comparative studies of g-C_3N_4. These studies scrutinize the structural, morphological, and electrochemical characteristics of the materials. It observes molybdenum disulfide nanoflowers on the graphitic carbon nitride nanosheet morphology, g-C_3N_4 agglomerates on polypyrrole nanotubes. And the Comparative investigations of graphitic carbon nitride at various temperatures, which are greatly improved the physical properties and mechanical

strength of the prepared samples. The electrochemical characteristics demonstrate the high specific capacitance, energy density, power density, columbic efficiency and cyclic stability.

2. Aims and objective of the present research work

1. To investigate the properties of 2D Material incorporation of conducting polymers, metal oxide, sulfides, 2D TMDs (Transition metal dichalcogenides) composite materials for supercapacitor applications.
2. To synthesize different composite by the hydrothermal method, chemical method, pyrolysis.
    i. Graphitic carbon nitride embedded with Molybdenum disulfide nanoflower.
    ii. Micelles Self-Degraded Template based 2D Graphitic Carbon Nitride-Polypyrole nanotube composite.
    iii. Graphitic carbon nitride through a pyrolysis technique at various temperatures.
3. To characterize samples by using FT-IR spectra, XRD, Raman spectra, EDAX and XPS technique, TG Analysis, BET analysis and surface morphology, elemental mapping images recorded with help of FESEM, and HR-TEM technique.
4. To fabricate supercapacitor electrode of the 2D Material based composite and examined the electrochemical performance by using a cyclic voltammetry (CV), charging-discharging (GCD), electron impedance spectroscopy (EIS) and electrochemical cyclic stability.

3. Novelty of the present work

The novelty of the present study is reports recent advancement of two-dimensional (2D) material-based supercapacitors, and to prevent agglomeration, stacking during the electrochemical process. 2D materials such as graphitic carbon nitride, 2D transition metal chalcogenides, are used for boosting the performance of supercapacitors applications by incorporating the high conducting polypyrrole, 2D metal chalcogenide molybdenum disulfides. Herein, the constituents, structural features, morphology, specific surface area, elemental analysis and electrochemical behavior of several 2D-based electrodes for supercapacitors are reviewed and significant improvement in the electrochemical capacities. The notable results are achieved here, Graphitic carbon nitride – molybdenum disulfide composite achieved notable specific capacitance (Csp) of 1122.89 F/g at 2 A/g current density (CD) as well as high-power density (PD) of 2072.46 W/kg and energy density (ED) of 345.41 Wh/kg. Noteworthy is that the CNM-2 composite extended cycle life, retaining 88.24% capacitance and exhibiting 92.86% coulombic efficiency after 8000 charging-discharging cycles. And the Graphitic carbon nitride – polypyrrole composite is achieved high specific capacitance (Csp) of 514.28 F/g at a current density (CD) of 1.2 A/g. The new, most significant 2D material-based composite exhibits a higher specific capacitance, making it a cost-effective and large-scale product for the development of energy storage devices and other devices.

The brief sketch of the proposed thesis

The main purpose of this thesis is to make, describe, and test 2D material-based composites that can be used in all-solid-state symmetric supercapacitors using electrochemical workstation. The thesis contains six chapters. The first chapter includes an introduction to 2D materials and conducting polymers, metal oxide, TMDs, and metal sulfide composites, as well as their use in supercapacitors and applications. The second chapter discusses the numerous approaches used in the synthesis, characterization, and fabrication of 2D material-based supercapacitors. The third to fifth chapters discuss the results of the experiments conducted to achieve the study objectives. The sixth chapter discusses the summary and conclusion, then moves on to reference sections and a list of research papers.

Chapter I: Introduction

This chapter elaborates the broad information about the polymer, 2D material and their composite, classification, physical properties as well as their use in supercapacitors. The chapter provides a fundamental overview of supercapacitors, encompassing their history, charging-discharging, working principle, and applications. It also encompasses a comprehensive review of related literature and a detailed explanation of the work's aim and objective.

Chapter II: Materials, Characterization and Fabrication Methods

This chapter describes the synthesis methods for conducting polymers and 2D materials such as a graphitic carbon nitride, molybdenum disulfide, and composite materials. The various characterization methodologies utilized to investigate material characteristics such as structural, morphological, thermal, and electrochemical properties. This section also covers the fabrication of electrode materials for supercapacitor devices of various configurations and electrolytes.

Chapter III: Preparation, characterisation and electrochemical performance of 2D Graphitic carbon nitride - 2D Molybdenum Disulfide composite for Symmetrical Supercapacitor

In this chapter, the synthesis of graphitic carbon nitride involved a direct pyrolytic technique, and the Graphitic carbon nitride (gCN) - Molybdenum disulfide (MoS) composites was achieved using a hydrothermal method. This composite characterized by various techniques such as Fourier Transform Infrared (FTIR), X-ray diffractometry (XRD), Field Emission Scanning Electron Microscope (FESEM), and Thermogravimetric Analysis (TGA). This comprehensive analysis aimed to investigate the chemical transformations, structural phases, morphology, and thermal properties of the composite. A two-electrode configuration was utilized to evaluate the electrochemical performance, revealing that the graphitic carbon nitride - molybdenum disulfide (CNM-2) composite achieved notable specific capacitance (Csp) of 1122.89 F/g at 2 A/g current density (CD). Additionally, the constructed symmetrical device showcased a high-power density (PD) of 2072.46 W/kg and energy density (ED) of 345.41 Wh/kg. Noteworthy is the CNM-2 composite extended cycle life, retaining 88.24% capacitance and exhibiting 92.86% coulombic efficiency after 8000 charging-discharging cycles. These results suggested that the CNM-2 composites are a highly promising electrode material for supercapacitor applications.

Chapter IV: Micelles Self-Degraded Template based 2D Graphitic Carbon Nitride Polypyrrole composite electrode for high Supercapacitor performance

This chapter synthesizes graphitic carbon nitride (gCN) using the simple pyrolysis method. The graphitic carbon nitride-polypyrrole nanotube composite (gCNPNT) was prepared through the micelles self-degraded template method by altering the amount of gCN. The structural, chemical,

and morphology of the composite were characterized by X-Ray diffraction, Fourier transform infrared spectra (FT-IR), Raman spectroscopy, and field emission scanning electron microscopy (FESEM) techniques. Thermal stability was examined by thermal gravimetric analysis (TGA). The electrochemical analysis of Galvano charging-discharging (GCD) curves and found that they had a high specific capacitance (Csp) of 514.28 F/g at a current density (CD) of 1.2 A/g. The cyclic voltammetry (CV) curve for the gCNPNT electrode shows pseudocapacitive behavior with effective reduction and oxidation rate, as well as a high Csp of 325 F/g at a scan rate of 10 mV/s. These results demonstrate gCNPNT-2 is a prominent candidate in energy and conversion device applications.

Chapter V: Synthesis, characterization and electrochemical performance of Graphitic carbon nitride material for supercapacitor application

This chapter elaborates, g-C_3N_4 sample were prepared by pyrolysis of melamine at different temperatures and the synthesised gCN material graphitic phase is confirmed by X-ray diffraction analysis, the layered structure of the sp^2 hybridised C-N bonding features is shown by FT-IR analysis. FESEM analyses provide insights into the morphology of gCN. Elemental identification and oxidation states were investigated using X-ray photoelectron spectroscopy (XPS). The electrochemical properties of gCN are performed using a two-electrode system with PVA/KOH electrolyte. The gCN nanostructure shows a specific capacitance of 183.20 F/g at a current density (CD) of 2 A/g, an energy density (ED) of 30.44 Wh/kg, and a power density (PD) of 2739.6 W/kg. Furthermore, the gCN nanostructure shows an excellent cycle life with 87.11% capacitance retention and 98.13% coulombic efficiency. These investigations clarify the electrochemical properties of gCN as an electrode material for supercapacitors.

Chapter VII: Conclusions and Scope for future work

This chapter summarizes the present results and outline of the future work and opportunity in this field.

References

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List of Journal Publications

1. A Paper entitled '*Micelles self-degraded template based 2D graphitic carbon nitride-polypyrrole nanotube composite electrode for high supercapacitor performance'* published in ***Diamond and Related Materials***, *139* (2023) 110257.
   Vijaykumar S P, Sapna S, Suresh D S, Ganesha H, Veeresh S, Nagaraju Y S, Devendrappa H. https://doi.org/10.1016/j.diamond.2023.110257

2. *'Aesthetic synthesis and comparative study of graphitic carbon nitride for energy storage applications,* published in ***Advances in Materials and Processing Technologies***, 17 Jul 2024.
   Vijaykumar S P, Suresh D S, Sapna S., Ganesha H, Abdullah Ba Shbil & Devendrappa H. https://doi.org/10.1080/2374068X.2024.2379084.

3. A Paper entitled *"Tailored Synthesis of CN-PPy Composite for Enhanced Electrochemical Functionality"* published in ***IOP Conf. Ser.: Mater. Sci. Eng.*** 1300 (2024) 012009.
   Vijaykumar S P, Sapna S, Suresh D S, Ganesha H, Abdullah Ba Shbil. doi:10.1088/1757-899X/1300/1/012009.

4. A paper entitled "Synthesis and characterization of graphitic carbon nitride material used for comparative study towards electrochemical applications." Published in ***AIP Conference Proceedings***, 28 January 2025 Vol. 3198, No. 1.
   Pujar Siddappa Vijaykumar, Sharanappa Sapna, D. S. Suresh, Honnu Ganesha, Ba Shbil Abdullah, Hundekal Devendrappa. https://doi.org/10.1063/5.0248282

5. A Paper entitled *'Synthesis of water-soluble nitrogen doped carbon quantum dots-polypyrrole nanocomposite via in-situ polymerization for high performance supercapacitor application'* published in ***Journal of Energy Storage*** 74 (2023) 109371.
   Sapna Sharanappa, **Vijaykumar S P**, Suresh D S, Abdullah Ba Shbil, H Ganesha, Veeresh S, Nagaraju Y S, Devendrappa H. https://doi.org/10.1016/j.est.2023.109371.

6. *'Synthesis and characterisation of tamarind seed husk-derived carbon quantum dots incorporated polypyrrole nanosphere composite for energy storage applications'* published in ***Advances in Materials and Processing Technologies***, 15 Jul 2024,
   Sapna S, **Vijaykumar S P**, Suresh D S, Ganesha H, Abdullah Ba Shbil & Devendrappa H. https://doi.org/10.1080/2374068X.2024.2379083.

7. A Paper entitled 'Simultaneous synthesis of carbon quantum dots and porous carbon using one step hydrothermal method for supercapacitor applications' published in ***IOP Conf. Ser.: Mater. Sci. Eng.*** 1300 (2024) 012003.
   Sapna Sharanappa, **Vijaykumar S P**, Suresh D S, Ganesha H, Abdullah Ba Shbil, Basappa M. doi:10.1088/1757-899X/1300/1/012003

8. A Paper entitled *'Novel approach towards optically active and hexagonal plate morphology of Zinc doped Perylene Tetra Carboxylic Di Anhydride composite for high photovoltaic and flexible supercapacitor performances'* published in ***J. of Power Sources,*** 593 (2024) 233967.
   Suresh D S, **Vijaykumar S P**, Sapna Sharanappa, Abdullah Ba Shbil, H Ganesha, Veeresh S, Nagaraju Y S, Devendrappa H. https://doi.org/10.1016/j.jpowsour.2023.233967

9. A Paper entitled "Hydrothermal synthesis of Rose Bengal dye particle deposition on layered reduced graphene oxide composite for photo assisted supercapacitor applications" published in ***Electrochimica Acta*** 511 (2025) 145380
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10. Paper entitled '*Optical Study on Co-Sensitization of Betanin Dye with Cadmium Sulfide to Fabricate Dye Sensitized Solar Cell*' published in **journal of environmental nanotechnology,** Vol. 13(3), 152-160 (2024).
    D. S. Suresh, Sapna Sharanappa, **S. P. Vijaykumar**, Abdullah Ba Shbil, H. Ganesha and H. Devendrappa*. https://doi.org/10.13074/jent.2024.09.242671

11. A Paper entitled *'Optical Properties of Lawsone dye doped with Zinc Oxide for the Fabrication of Dye Sensitized Solar Cell'* published in ***IOP Conf. Ser.: Mater. Sci. Eng.*** 1300 (2024) 012002.
    Suresh D S, Abdullah Ba Shbil, **S P Vijaykumar**, Sapna Sharanappa, H Ganesha. doi:10.1088/1757-899X/1300/1/012002

12. A Paper entitled *'Enhancement of crystallinity with porosity material through solvent and thermal treated eggshell waste for high-performance supercapacitor applications'* published in ***Journal of Material Science: Materials in electronics*** 35, 330 (2024).
    Suresh D S, Abdullah Ba Shbil, Sapna Sharanappa, **S P Vijaykumar**, H Ganesha, S Veeresh, Y S Nagaraju, H Devendrappa. https://doi.org/10.1007/s10854-024-12021-9.

13. A Paper entitled '*Synthesis, characterization ofcadmium sulfide doped polymer P3HT for energy storage applications*' published in ***AIP Conf. Proc.12 January 2024***; 2995(1): 020181. Suresh D S, S Veeresh, H Ganesh, Y S Nagaraju, **S P Vijaykumar**, Sapna Sharanappa, H Devendrappa. https://doi.org/10.1063/5.0178459.

14. A Paper entitled '*Polymer incorporated with graphene oxide composite for high electrochemical performance*' published in ***Materials Today: Proceedings*** (2023), Ganesha H, Veeresh S, Nagaraju YS, Suresh D S, **Vijaykumar SP**, Sapna S, Devendrappa H. https://doi.org/10.1016/j.matpr.2023.04.35

15. A Paper entitled '*Nilgiri tree peels-derived activated porous carbon for high performance supercapacitor applications'* published in ***IOP Conf. Ser.: Mater. Sci. Eng.*** 1300 (2024) 012010.
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16. A Paper entitled ‘Sustainable Approach to Fabricate High-Performance Symmetry Supercapacitor Electrodes from Natural Coconut-Shell-Derived Porous Activated Carbon with Nickel Oxide Nanocomposites’. published in ***ACS Omega*** 10 (2025) 11077-11090
    Abdullah Ba shbil, Nagaraju Yennappa Siddappa, Suresh Daddi Suraiah, Ganesha Honnu, **Vijaykumar Siddappa Pujar,** Sapna Sharanappa, Devendrappa Hundekal. https://doi/full/10.1021/acsomega.4c09778

17. A Paper entitled ‘Bio-waste-derived one-step carbonized hierarchical structured carbon/cobalt oxide composite for energy storage application’ published in ***Ionics*** (2025) 1-14.
    Abdullah Ba shbil, Nagaraju Y. S, Ganesha H, Veeresh S, Suresh D. S, **Vijaykumar S. P,** Sharanappa, S, Devendrappa H. https://doi.org/10.1007/s11581-025-06072-z

18. Paper entitled ‘*One pot hydrothermal green Synthesis and characterization of tamarind seed husk derived carbon quantum dots for energy storage applications*’, published Conference Proceedings, International Conference on Emerging Advances and Applications in Green Energy (ICEAAGE-2024). 29th February 2024.
    Sapna Sharanappa, **Vijaykumar S P**, Suresh D S, Ganesha H, Abdullah Ba Shbil, Devendrappa H*. ISBN: 978-93-6128-558-5.

19. Paper entitled ‘One Step Self Assembled Bio-waste Carbon Material Derived from Maize Cob Doped ZnO/Co Composite Electrode Material For Battery Type and High Energy Density Supercapacitor’. published in ***Inorganic Chemistry Communications,*** (2025) 114712.
    H. Ganesha, M. Vandana, S. Sapna, **S. P. Vijaykumar**, D. S. Suresh, H. Devendrappa, Thongmee, S. https://doi.org/10.1016/j.inoche.2025.114712

Attended Conferences:

1. Participated and presented a paper entitled as *"Micelles Self-Degraded Template based 2D Graphitic Carbon Nitride-Polypyrrole nanotube composite electrode for Supercapacitor performance"* in the ICTN-KLC-2023 organized by Department of Physics, IIT Madras held from 6th – 8th July, 2023.
   Vijaykumar S P, Suresh D S, Sapna Sharanappa, Abdullah Ba Shbil, Ganesha H, Veeresh S, Nagaraju Y S, Devendrappa H.

2. Organizing Committee member and presented a paper entitled as *"Tailored Synthesis of CN-PPy Composite for Enhanced Electrochemical Functionality"* in the International Conference on Physics of materials and Nanotechnology (ICPN-2023) organized by Department of Physics, Mangalore University held from 21st - 23rd September, 2023.
   Vijaykumar S P, Sapna S, Suresh D S, Ganesha H, Abdullah Ba Shbil.

3. Participated and presented a paper entitled as *"Synthesis and Characterization of Graphitic Carbon NitrideMaterial used for Comparative Study Towards Electrochemical Applications"* in the 66th DAE Symposium (DAE SSPS -2023) organized by BARC, Gandhi Institute of Technology and Management (GITAM), Visakhapatnam. held from 20th– 24th December, 2023.
   Pujar Siddappa Vijaykumar, Sharanappa Sapna, D S Suresh, Honnu Ganesha, Ba ShbilAbdullah, Hundekal Devendrappa*

4. Participated and oral presentation entitled as "Aesthetic synthesis and comparative study of graphitic carbon nitride for energy storage applications" in the International Conference on Materials Manufacturing and Characterization (ICMPC-2024) conference, organized by Nirma University, Ahmedabad, from June 27-29, 2024.
   Vijaykumar S P, Suresh D S, Sapna S., Ganesha H, Abdullah Ba Shbil, Devendrappa H.

5. Participated in 5 days online FDP on Advanced Functional Materials for science & Engineering (AFMSC-2023) Organized by Department of chemistry on 15th May 2023 to 19th May 2023 at Don Bosco Institute of Technology, Bangalore, Karnataka.

6. Participated in the International conference Advanced characterization techniques (ACT-2023) organized by Indian institute of science, Department of Materials engineering. Bangalore. On 18th August 2023.

Attended Workshops:

Sl No.	Organization	Period		Details of Training / Project undertaken
		From	To	
1.	Department of Education, Mangalore University, Konaje.	18th February, 2022.	23rd February, 2022.	Six days workshop on "**Research Publication & Ethics.**"
2.	Online webinar	17th June, 2022.	17th June, 2022.	International webinar on "**Nanopore sequencing overview and application.**"
3.	CENSE, Indian Institute of Science, Bangalore.	20th June, 2022	22nd June, 2022	Virtual **INUP Basic Training Programme**
4.	Lab India Analytical Instruments Pvt. Ltd., Bangalore.	2nd September 2022.	2nd September 2022.	"**NMR-A Boon for advanced research"** High-resolution cryogen free benchtop spin solve NMR for advanced research.
5.	Department of Physics, Maharani Lakshmi Ammanni College for Women Autonomous, Malleswaram, Bengaluru funded by Science Academies.	7th December, 2022.	22nd December, 2022.	15 days **"Refresher Course in Experimental Physics**."
6.	Computer Centre, Mangalore University.	18th January, 2023.	19th January, 2023.	Two Days **"Workshop on Latex Programming".**
7.	Indian Association of Physics Teachers (RC-1). University of Delhi, Delhi, India.	28th of January, 2023.	28th of January, 2023.	"**FEMTO Physics and its applications**."
8.	Mangalore University, on 20 June 2024.	20th June, 2024.	20th June, 2024.	One day "**Workshop on Open Access Publishing**."

Devendrappa H
(Research Guide)

Vijaykumar Siddappa Pujar
(Research Scholar)